Indian J. Phys. **75B** (3), 175–177 (2001)

I J P B
— an international journal

Ferrite loading effects on electromagnetically coupled patch antenna

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Abstract : The composition and thickness dependent effects due to ferrite loading (overlay) on electromagnetically coupled rectangular patch antenna is reported in this paper. The effect of variation in feed position is also studied The long side feed and diagonal feed positions show different behaviour due to ferrite loading as compared to short side feeding position The resonance frequency decreases and peak transmittance increases dramatically due to ferrite pellet overlay.

Keywords : EMC patch antenna, ferrite, feedline

PACS Nos. : 78.70.Gq, 75.50.Gg

1. Introduction

The microstrip patch antenna with microstripline electromagnetically coupled feed system is not studied much and particularly the flexibility aspect of it is not fully explored, even experimentally. The electromagnetically coupled patch antenna has the advantage of variation of feedline giving additional degrees of freedom. Ferrite materials in microstrip structures can cause changes in the properties of structure. Due to the interaction of the ferrite with the radio frequency field the permeability changes. The microstrip antenna on biased ferrite substrate has been studied by various workers. The use of ferrite as overlay instead of substrate has not been investigated much. The use of overlay gives more flexibility to the system. This paper reports the effect of ferrite of different composition $Mg_{0.8}Fe_2O_4$, $Mg_{0.4}Fe_2O_4$, $Mg_{0.6}Mn_{0.3}Zn_{0.2}Al_{0.8}Fe_2O_4$ and $Mg_{0.4}Mn_{0.5}Zn_{0.2}Al_{0.8}Fe_2O_4$ and different thickness on the output of electromagnetically coupled rectangular patch antenna. The antenna patch and the microstrip feed line were of Ag thick film. The effect due to feed point variations is also reported. The antenna properties are controlled by its application environment and also by mode of feeding.

2. Experimental

The electromagnetically coupled antenna was designed according to Bahl and Bhartia [1] and Splitt and Davidovitz [2]. The dimensions of antenna were of width 0.6432 cm and length 0.4719 cm. The rectangular patch and the microstrip feedline were fabricated on two separate substrate (size 1" × 1" × 0.025") using thick film technology. The metallisation of silver thick film having a thickness of the order of 7 μm. The patch was fed from long side, short side and diagonally successively. The X-band output was measured point by point using a system consisting of Gunn source, isolator, attenuator, pyramidal horn and detector. SMA connectors were used for contact to antenna. The ferrite overlay was in pellet form of diameter 1 cm and thickness ranging from 0.1 cm to 1.1 cm. The ferrite used as overlay were of composition $Mg_{0.8}Fe_2O_4$, $Mg_{0.4}Fe_2O_4$, $Mg_{0.6}Mn_{0.3}Zn_{0.2}Al_{0.8}Fe_2O_4$ and $Mg_{0.4}Mn_{0.5}Zn_{0.2}Al_{0.8}Fe_2O_4$. The variations in the output voltage as a function of frequency for various thickness of pellet overlay and various composition were studied for the three different feeding positions. The pellet overlay was kept at the center of the microstrip patch antenna. The electromagnetically coupled antenna was used as the transmitting antenna and the pyramidal horn kept at far field position was the receiving antenna, which was connected to the detector.

3. Results and discussion

Without overlay the antenna had a resonance frequency at 10 GHz for long side fed and diagonally fed whereas for

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short side fed the resonance frequency was 9.7 GHz. The Q of the patch was 28.95 when long side fed, 56.57 when diagonally fed and 164.9 when short side fed.

Figure 1 depicts the frequency *versus* output voltage curve for the three different feed positions for $Mg_{0.8}Fe_2O_4$ overlay.

From the figure, it is seen that on placing the ferrite pellets the frequency shifts to 9.7 GHz for long side fed and diagonally fed and for short side fed the shift is to 9.85 GHz. For other composition, there is no shift in the resonance frequency when antenna is fed from the short side, but for the other two feedings, other compositions behave identical to $Mg_{0.8}Fe_2O_4$. Due to this, only one composition is plotted.

From the figure, it is also seen that for overlay with least thickness higher peak output voltage is observed and it decreases with increase in thickness of overlay till the thickness of 0.45 cm and again increases. In all the cases the peak output voltage is very much higher than the no overlay case. The Q of the antenna has also increased dramatically due to overlay. Q seems to depend more on composition and less on the thickness of ferrite overlay. When the antenna is fed diagonally, peak output voltage varies due to overlay but as thickness increases, the peak output voltage also increases. Here also Q increases due to overlay for all composition. Q seems to be independent of thickness of the overlay and also composition. For the short side feeding case, though there is increase in peak output voltage due to overlay the increase is comparably lesser than long side fed and diagonally fed condition.

The data of bandwidth and Q of some typical thickness are tabulated in Table 1. The Q shows increase due to $Mg_{0.8}Fe_2O_4$ overlay but for other overlays there is not much change, in some cases Q decreases.

Table 1. Data of bandwidth and Q factor

Feeding	Thickness cm	Properties	Composition			
			I	II	III	IV
	0.111	B W MHz	54.5	50.86	50.0	61 53
		Q	177.98	190.72	194.0	154 56
LSF	0.577	B W MHz	48 5	58 69	54 5	69 21
		Q	200 0	165.28	177 98	140 11
	1 11	B W MHz	54 5	56.5	50.0	69 23
		Q	177 98	171.0	194 0	140 11
	0 111	B W MHz	64.45	64 29	54.31	64 29
		Q	148 19	150 89	178 6	150 88
DF	0.577	B W MHz	65.45	64.29	62 07	64 29
		Q	148 19	150 89	156 28	150 88
	1 11	B W MHz	57.27	64 29	62.07	64 29
		Q	169 37	150.89	156 28	150 88
	0 111	B W MHz	33 89	57 14	58 8	61 51
		Q	290.59	169.75	164 3	150 15
SSF	0 577	B W MHz	33 89	62 86	58 8	56 45
		Q	290.59	154 32	164 9	171 82
	1 11	B W MHz	42 37	62.86	58 8	64 51
		Q	232.46	154 32	154 9	150 [illegible]

LSF–Long side fed, DF–Diagonally fed, SSF–Short side fed

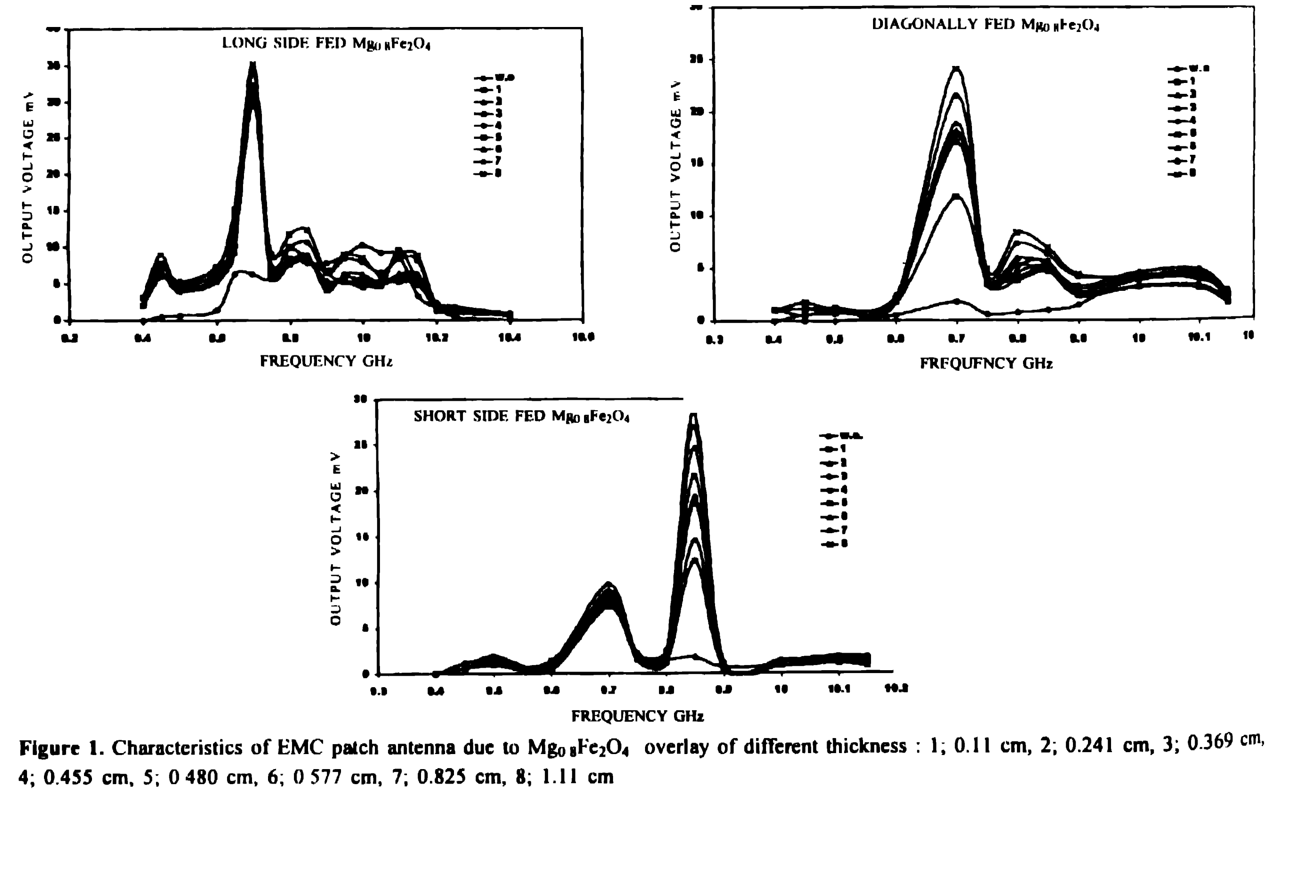

Figure 1. Characteristics of EMC patch antenna due to $Mg_{0.8}Fe_2O_4$ overlay of different thickness : 1; 0.11 cm, 2; 0.241 cm, 3; 0.369 cm, 4; 0.455 cm, 5; 0 480 cm, 6; 0 577 cm, 7; 0.825 cm, 8; 1.11 cm

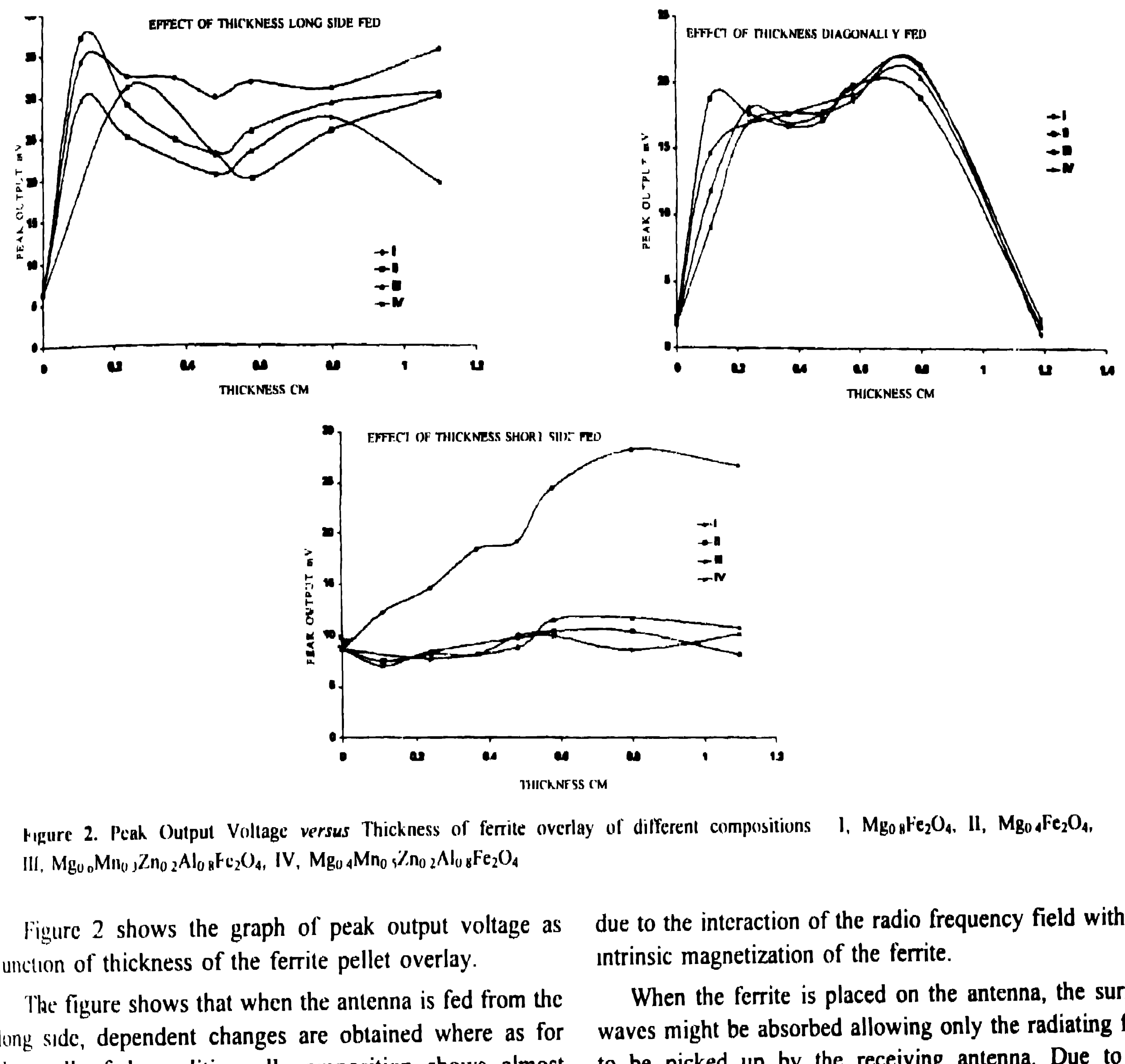

Figure 2. Peak Output Voltage *versus* Thickness of ferrite overlay of different compositions I, $Mg_{0.8}Fe_2O_4$, II, $Mg_{0.4}Fe_2O_4$, III, $Mg_{0.0}Mn_{0.3}Zn_{0.2}Al_{0.8}Fe_2O_4$, IV, $Mg_{0.4}Mn_{0.5}Zn_{0.2}Al_{0.8}Fe_2O_4$

Figure 2 shows the graph of peak output voltage as function of thickness of the ferrite pellet overlay.

The figure shows that when the antenna is fed from the long side, dependent changes are obtained where as for diagonally fed condition all composition shows almost similar output voltage variations. When the antenna is fed from the short side except for $Mg_{0.8}Fe_2O_4$ all other ferrite compositions shows similar thickness-dependent effects.

All the overlay observations were taken in the absence of external magnetic field. Since the patch was kept in such a way that its center was on the edge of the feed line, when ferrite overlay is placed at the center it also covers the feed line. The fringing field present on the microstripline gets reflected back into the feed line gives more power to the patch. Since the ϵ_{eff} changes due to the overlay matching of patch to the feed line might be taking place whereby increase the peak output voltage. Since external magnetic field is not applied the ferrites are magnetically nonsaturated. Apart from changes in ϵ_{eff}, the μ_{eff} might also be changing due to the interaction of the radio frequency field with the intrinsic magnetization of the ferrite.

When the ferrite is placed on the antenna, the surface waves might be absorbed allowing only the radiating field to be picked up by the receiving antenna. Due to the elimination/suppression of the surface mode, the antenna output be more than no overlay situation.

4. Conclusions

With proper combination of feed position and overlay composition and thickness, we can tailor the antenna properties to suit the applications. External dc magnetic field might give added dimension to the flexibility of the antenna properties so that multi frequency operation becomes feasible.

References

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[2] G Splitt and M Davidovitz *IEEE* AP-38 1136 (1980)